Chapter I
Profile of Screen Reclamation Use Cluster

Profile of Screen Printing

Overview of Screen Printing

Screen printing is probably the most versatile of the printing techniques, since it can place relatively heavy deposits of ink onto practically any type of surface with few limitations on the size and shape of the object being printed. The ability to print variable thicknesses of ink with a high quantity of pigment allows for brilliant colors, back lighting effects, and durable products which are able to withstand harsh outdoor weather conditions and laundering. Unlike many other printing methods, substrates for screen printing can include all types of plastics, fabric, metals, papers, as well as exotic substrates such as leather, masonite, glass, ceramics, wood, and electronic circuit boards.[1] While screen printing does compete with other printing techniques for some products (especially for small paper substrate products), it has a specialized market niche for many graphic art materials and textile printing applications. Comparatively low equipment investment costs allow for low cost short production runs.

The screen printing process involves stretching a porous mesh material over a frame to form a screen. Part of the screen mesh is blocked by a stencil to define the image. A rubber-type blade (squeegee) is swept across the surface of the screen, pressing ink through the uncovered mesh to print the image defined by the stencil. The substrate is then either manually placed onto drying racks or placed onto a conveyor transport system for conveyance into a drying unit. The screen and its stencil can be used repeatedly to print the same image multiple times.

The screen printing process differs in many ways from the other printing methods of lithography, gravure, flexography, and letterpress. Because screen printing utilizes various materials in a printing process that differs greatly from other printing methods, it presents environmental challenges that are unique in the printing industry.

Products Printed

The majority of screen printers do not restrict their operations to printing on one substrate or to the production of one end product. Textile products, however, are the most common products in production. Surveys conducted by the Screen Printing Association International (SPAI) show that approximately 54 percent of screen printers produce imprinted textile garments.[2] Perhaps the most well known example is T-shirts. Textile printing also includes the markings and patterns on towels, comforters, caps, visors, aprons, drapes, carpet, sheets, flags, and the basic patterned material that is made into pants, dresses, and other clothing.

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[1]Types of plastics used as substrates include acrylic, epoxies, vinyl, topcoated and nontopcoated polyester, and polycarbonate, while fabric substrates can be either natural or synthetic. Metals used as substrates include aluminum, brass, copper, lacquer-coated metals and steels. Paper substrates range from uncoated, coated and corrugated coated fiberboard to poster and cardboard.

[2]Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 9.

Another major category of screen printed products includes graphic arts materials with products as diverse as fine art prints, billboard advertisements, point-of-purchase displays (such as those displayed in supermarkets), posters, plastic banner wallhangings, wallpaper, and decals. Large banners, durable outdoor displays, and short poster runs are specialty products of many commercial screen printing establishments.

Other applications include original equipment manufacturing (for example, the soft keypad on cash registers at some fast food restaurants or the heating controls in a car), printing on electronic equipment such as circuit boards, and product identification markings on products like wine bottles, fire extinguishers, cosmetic compact covers, insulated beverage and food containers, and aerosol spray cans.

Market Information on the Screen Printing Industry

Number of Screen Printing Facilities

The number of American screen printers and the quantity of their sales is difficult to determine because parts of the screen printing industry are "captive in-plant screen departments" within a separate manufacturing industry. For example, one step in toothpaste production is screen printing product identification markings on the tube.

There are three major categories of screen printing facilities:

- Commercial Screen Printing Facilities (garments, signs, posters, decals, etc.)
- Industrial Screen Printing Facilities (panel fronts, circuits, glassware, original equipment, etc.)
- In-Plant (Captive) Screen Printing Departments (markings and decals on products)

SPAI estimates that there are at least 40,000 plants in the U.S. with screen presses, consisting of approximately 20,000 plants that focus on textile substrates (50 percent) and 20,000 graphics printers.[3] This number is derived from known addresses of screen printing shops. This estimate includes in-plant operations and the majority of industrial screen printing operations.[4]

Quantity of Sales and Percent of Market

According to Bruno's *Status of Printing 1989-90*, screen printing accounted for less than three percent of the total value of U.S. printing industry output in 1991. This figure excludes in-plant "captured" printing. It has been estimated that the screen printing industry posted gross sales of $13 billion in 1986.[5] A statistical weighted average calculation performed from 1990 SPAI

[3]Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 9.

[4]Correspondence between Kathryn Caballero, U.S. EPA, and Marcia Y. Kinter, Director of Government Affairs, SPAI, May 1994.

[5]Air and Waste Management Association, *Air Pollution Engineering Manual*, Buonicore, Anthony and Davis, Wayne T. (ed.), (New York:Van Nostrand Reinhold, 1992), p. 288.

Survey Information estimated U.S. annual sales volume estimate of $21.9 billion in 1990.[6] According to Bruno, the screen printing market is expected to show little or no growth between 1995 and 2025.[7]

Size of Screen Printers

The Screen Printing Industry is dominated by small businesses with the average screen print shop having approximately 15 employees.[8] From a 1992 Survey, *Screen Printing Magazine* estimates the following size categories for screen printing facilities:[9]

- 1 to 20 employees (70.9 percent)
- 21 to 50 employees (14.0 percent)
- 51 to 100 employees (7.8 percent)
- More than 100 employees (7.4 percent)

The SPAI 1990 survey of U.S. screen printing companies showed that respondents had slightly more than 20 employees and of the 20, approximately 14 were production workers, two were managers/supervisors, two were sales personnel, and two were classified as "other".

Definition and Overview of Screen Reclamation

Definition of Screen Reclamation

For the purposes of the Design for the Environment Printing Project, screen reclamation will be defined as the process that begins once excess ink has been carded off the screen and ends when the screen is ready for reuse. Ink removal performed at press side was not evaluated as part of this project.

Overview of Screen Reclamation

Purpose of Reclamation

Many screen printing facilities reclaim their screens for reuse because the screen material is valuable and costly to replace. Screen fabric can be one of the more expensive supplies that a screen printer uses and can have a large impact on cost of operations. For example, the most commonly used fabric, polyester, costs $10 to $40 per square yard.[10,11] A shop that wastes $100

[6] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 10.

[7] *Bruno's Status of Printing 1989-90*, (1991), p. 17.

[8] Air and Waste Management Association, *Air Pollution Engineering Manual*, Buonicore, Anthony and Davis, Wayne T. (ed.), (New York:Van Nostrand Reinhold, 1992), p. 397.

[9] Duccilli, S., "The 1992 Industry Survey: Safety and Environmental Practices in the Screen-Printing Industry," *Screen Printing Magazine*, (April 1992), p. 50.

[10] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 15.

[11] Frecska, T., *Screen Printing Magazine*, (1992), p. 120.

to $200 per week, in fabric costs from ruining screens or failing to reclaim them, can increase its annual production costs by as much as $5000 to $10,000.[12] The average monthly expense for fabric is $360.[13] In addition, reclaiming screens has the advantage of saving labor time needed for stretching mesh across the frame and adjusting it to the correct tension. Some printers believe that using retensionable frames when stretching the mesh "work hardens" the fabric, improving the printability and longevity of the screen. Other printers note that reusing screens for other jobs, instead of storing them in an imaged screen inventory, saves both screen fabric costs and storage space often needed for presses.

Screen Reclamation Frequency

While 90.3 percent of screen printers reclaim screens daily,[14] not all screen printers attempt to reclaim every screen. Some orders of a specific stencil may be reordered systematically (for example, a stop sign or sale poster), in which case a screen printer may want to store the screen and stencil until the customer returns and requests another run of the print. In other cases, the screen may be very small (for example, a message printed on an plastic aspirin bottle). When screens are small, the time and effort needed to reclaim the screen can be higher than the cost of cutting out the fabric and replacing it.[15]

SPAI's 1990 Industry Profile Study reports that 68 percent of respondents reclaim between 1 and 10 screens per day and 17.3 percent reclaim between 11 and 20 screens per day.[16] Many operational factors determine the lifetime of a screen, including the roughness of substrate and ink, number of impressions, the daily handling of the screen, and the types of products used to reclaim the screen. The number of impressions printed affect the screen lifetime because repeated runs of the squeegee over the fabric can weaken and warp the fibers of the mesh. A printer may mark and date screens to keep track of the screen history, including number of impressions. Printers discard the screen when it has been reclaimed a certain number of times or shows signs of weakening.[17]

Screen Reclamation Process

> *Screen cleaning is the forgotten process in our industry. It generally takes place in a dungeon-like area in the most remote corner of the shop. As a result, the forgotten process has developed differently in every screen-printing business. Walk into ten shops and you could easily find just as many different solvents and disposal methods being used. -- Steven Duccilli, Editor.*[18]

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[12] Frecska, T., *Screen Printing Magazine*, (1992), p. 120.

[13] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 16.

[14] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 23.

[15] Personal communication between Beverly Boyd, U.S. EPA, and Dutch Drehle, Screen Printing Association International, May 1993.

[16] Screen Printing Association International, *1990 Industry Profile Study*, (Fairfax, Va.: 1991), p. 23.

[17] Personal communication between Beverly Boyd, U.S. EPA, and Dutch Drehle, Screen Printing Association International, May 1993.

[18] Duccilli, S., "In Search of Screen-Cleaning Standards," *Screen Printing Magazine*, (April 1993), p. 6.

While screen reclamation techniques may vary significantly from one screen printer to another, two basic functions must be performed in order to restore a used screen to a condition which it can be reused: removal of ink and removal of emulsion (stencil). A third step, removing any remaining "ghost image" or haze, may be required depending upon the type of ink used, effectiveness of ink removal and/or emulsion remover products, and the length of time that ink and stencil have been on the screen.

A variety of commercial products have been developed to perform each of these functions and a complementary series of products (i.e., a particular brand of ink remover product, emulsion remover product, and haze remover product) are often sold by manufacturers and distributors as a package. **For the purposes of this project, the trade-off issues associated with a particular *screen reclamation system*, consisting of an ink remover, emulsion remover and haze remover, are typically assessed**. Other products, such as screen degreaser and ink degradant, sometimes play a role in the reclamation of screens. These are not assessed. Different equipment, application techniques, and work practices play a role in the efficacy and quantity required of each product. All of these affect the trade-offs associated with product systems.

Ink Removal

Ink categories include: traditional solvent-based inks (which includes enamels), ultraviolet (UV)-curable inks, water-based inks and plastisols (for textile printing). Ink removal (also called screen washing or screen cleaning) precedes stencil removal so that excess ink does not interfere with removal of the stencil.

Ink is also removed at other times prior to screen reclamation (for example, when dust gets into the ink and clogs the screen mesh, or at lunch break, to avoid ink drying on the screen). This "process cleaning" usually occurs at press side. Screen cleaning performed as a part of screen reclamation may be performed at press side, in a separate ink removal area of the shop, or in an area where emulsion and haze are removed. This study will focus on ink removal performed as a part of the screen reclamation process and not on process or press-side cleaning.

Emulsion (Stencil) Removal

Several types of emulsions or stencils, such as indirect or direct photo stencils, are used in transferring an image to the screen.[19] Most direct stencils are water-soluble and thus incompatible with water-based inks. However, chemical curing of water-soluble stencils can improve their resistance to water. A water-resistant stencil must accompany a solvent-based ink, and a solvent-resistant stencil must accompany a water-based ink. Solvent and UV curable inks are typically coupled with water-resistant emulsions. Thus, a commercial facility using 90 percent solvent-based inks and 10 percent UV curable inks can use the same water resistant emulsion systems for both inks. If, however, the screen printing facility wants to replace some of its solvent-based inks with water-based inks, a new type of solvent resistant emulsion will have to be used to complement the water-based inks. Using solvent-resistent emulsion with water-based inks will cause the emulsion to erode quickly and pinholes will show up in the stencil.

Most emulsion removers are packaged in a water solution or as a powder to be dissolved in water; the water acts as a carrier for the actual reclaiming chemical. The predominant chemical in an emulsion remover is often sodium metaperiodate. Because periodate needs water as a carrier

[19] Direct photostencils are exposed in direct contact with the screen, after adhesion to the mesh. Conversely, indirect photo stencils are exposed, developed and adhered to the mesh. Different chemicals are used for each type of stencil.

to reach certain chemical groups in the emulsion, it is more difficult to reclaim a water-resistant emulsion than one which is only solvent-resistant. Most commercially available emulsion remover products are able to remove either water resistant or solvent resistant emulsions. High pressure water spray can also facilitate emulsion removal and may lower the quantity of emulsion remover required. Special care must be taken to ensure that the emulsion remover does not dry on the screen, as the screen will become almost impossible to clean, even with repeated applications of the remover.

Haze (Ghost Image) Removal

A haze or ghost image is sometimes visible after the emulsion has been removed. This results from ink or stencil being caught in the knuckle (the area between the overlap of the screen threads) or dried/stained into the threads of the screen. Staining of the mesh frequently occurs when petroleum-based solvents are used in the ink removal process. The solvents dissolve the ink, leaving behind traces of the pigment and resin in the screen. The residual pigment and resin bonds to the screen after the solvent evaporates, leading to haze accumulation. Ghost images are especially common when dark inks (blue, black, purple and green) are used, or if an excessively long time period elapsed prior to ink removal from the screen. A ghost image is particularly likely when using solvent-based ink systems, as opposed to other ink systems. If the ghost image is dark or will interfere with later reimaging and printing, a haze remover product can be applied until the image disappears or fades. The level of cleanliness required at the end of the process varies depending on the kind of printing job that the screen will be used for after reclamation. Some printers can use screens with light ghost haze, others cannot.

Haze removal can potentially damage the screen mesh, particularly caustic haze removers that are traditionally used in the industry. The excessive use of these products, such as applying the chemical and leaving it on the screen too long, can weaken the mesh.

Printer Environmental Concerns about Screen Reclamation

Concern on the part of screen printers and SPAI about screen cleaning and reclamation stems from two sources; (1) the use of highly volatile organic solvents; (2) the common practice of screen printers of allowing water from screen washing and reclaiming to go directly down the drain without prior filtration. According to a 1992 survey by *Screen Printing* magazine, of the 250 companies that answered a question about the latter practice, 191 (76 percent) indicated they send unfiltered waste down the drain.[20] Depending on what is in the water (ink, ink remover chemicals, emulsion, emulsion remover chemicals, and/or haze remover) this practice could contribute to health and environmental problems since the water goes either directly to a wastewater treatment facility, a body of water (streams, etc.) or a printer's septic tank.

Publicly Owned Treatment Works (POTWs), particularly in the Western states, have increased awareness of the water discharge problem by tracing problem inputs into the sewer system back to screen printers and levying fines on offenders. Three major categories of concern have been raised by the POTWs:

- Heavy metals, which can be found in the residue of ink, can enter the sewer system and contaminate sewage sludge

[20] Duccilli, S., "The 1992 Industry Survey: Safety and Environmental Practices in the Screen-Printing Industry," *Screen Printing Magazine*, (April 1992), p. 53.

- Heavy concentrations of certain chemicals can disrupt the pH balance at the treatment plant and disrupt the bacterial systems essential to the sewage treatment process

- Combinations of mixtures with low flash points can cause flammability concerns in the sewage system

Concern has also been expressed about screen printing facilities that discharge waste water to septic tanks. In these cases, water containing ink cleaning solvents, ink residue, emulsion, emulsion remover, haze remover products or other wastes could disrupt the bacterial balance in septic tanks and/or contaminate local groundwater supplies.

Confusion has been exacerbated by "biodegradable", "drain safe", "solvent-free" claims on the labels of many ink removal and emulsion removal products. Unfortunately, some printing facilities that use so-called "biodegradable" products have mistaken these products for waste-disposal panaceas. Simply because the product itself is drain permissible, does not mean that the product combined with ink residue or emulsion residue from screen reclamation is also drain permissible. Also, something which is currently drain permissible may contribute environmental problems and may be subject to future regulation. Printers should always check with local, state and federal water regulations prior to discharging a product marked "drain-safe" to water. An effort to ascertain the environmental or health impact of the chemical may also be prudent.

While water concerns have inspired interest in this area, this Substitute Assessment document presents an analysis of cross media effects (air, waste disposal, etc.) and will outline the trade-off issues that are associated with different screen reclamation options, such as occupational exposure concerns, total cost differences, performance effectiveness and toxicity of waste water.

Identification of Screen Reclamation Functional Groups

Figure 1-1 is a graphical model of the integration of all screen reclamation methods. It separates the basic components of any screen reclamation process into five functional groups: ink removal, screen degreasing, ink degrading, emulsion (stencil) removal and haze removal. A general flow chart is depicted for the integration of these functional groups. However, this flow chart may not be representative of all types of screen reclamation *processes*. Several steps that may be included in the reclamation process are low-pressure and high-pressure water rinsing, which typically involve different equipment. Preparation of the screen or disposal of waste from screen reclamation are not included in this basic flow chart.

To concentrate on those functional groups most often associated with screen reclamation, this CTSA focuses on the three functional groups of ink removal, emulsion removal and haze removal. The parameters associated with the use of screen degreaser and ink degradant are *not* discussed.

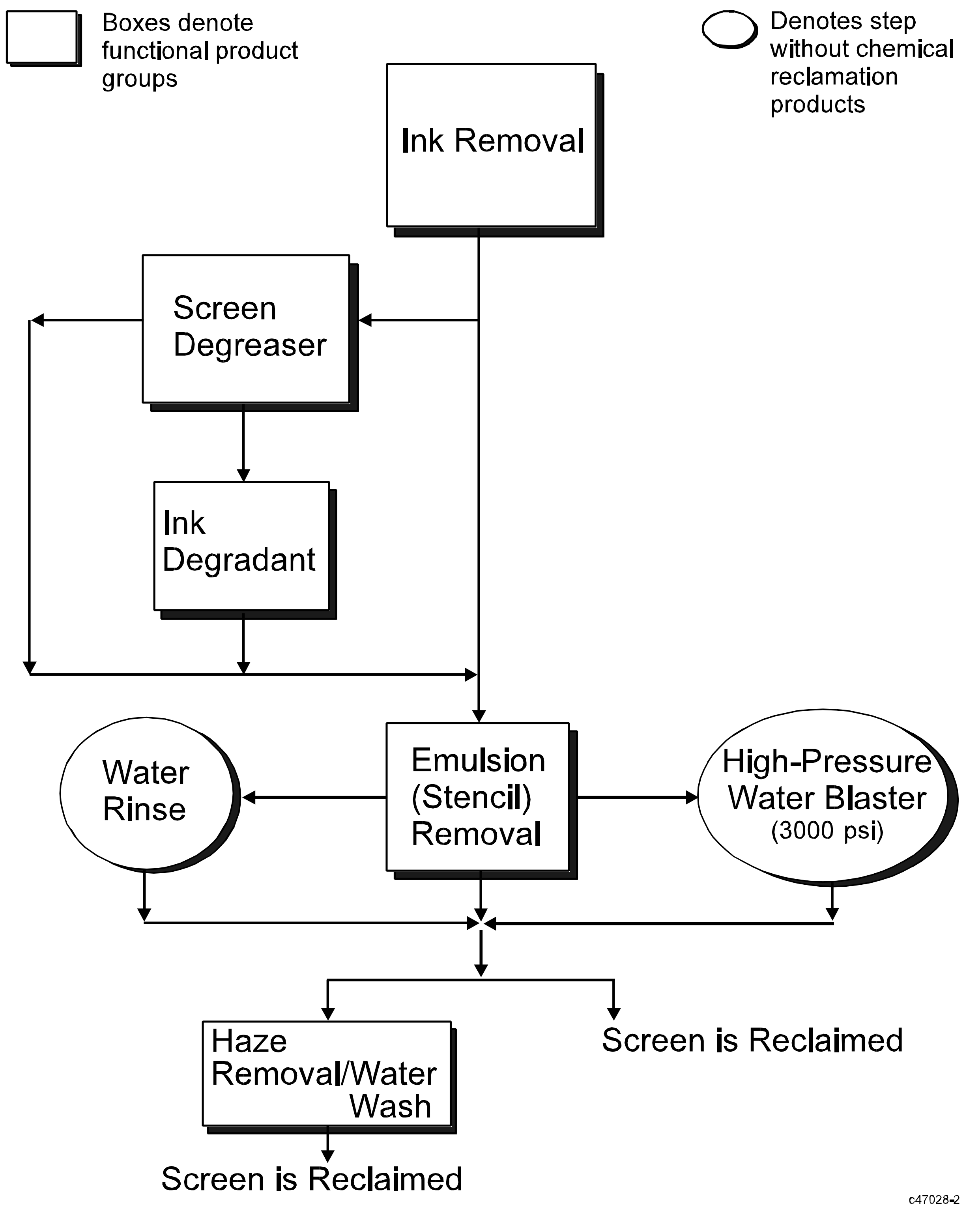
Identification of Screen Printing Substitute Trees for Screen Reclamation

Figure I-2 depicts the five main methods (including the automatic screen washer) that are used in screen reclamation. Because the actual process of screen reclamation can be performed using any of these methods, these methods "substitute" for each other in screen reclamation. In addition to the five methods, the substitute tree also suggests that the disposal of the screen mesh without screen reclamation would be an option. This disposal option is considered in Chapter VI, Overall Pollution Prevention Opportunities for Screen Reclamation.

Figure I - 1

Identification Of Screen Reclamation Functional Groups

This Exhibit is an Integration of Screen Reclamation Methods



Identification of Screen Reclamation Functional Groups

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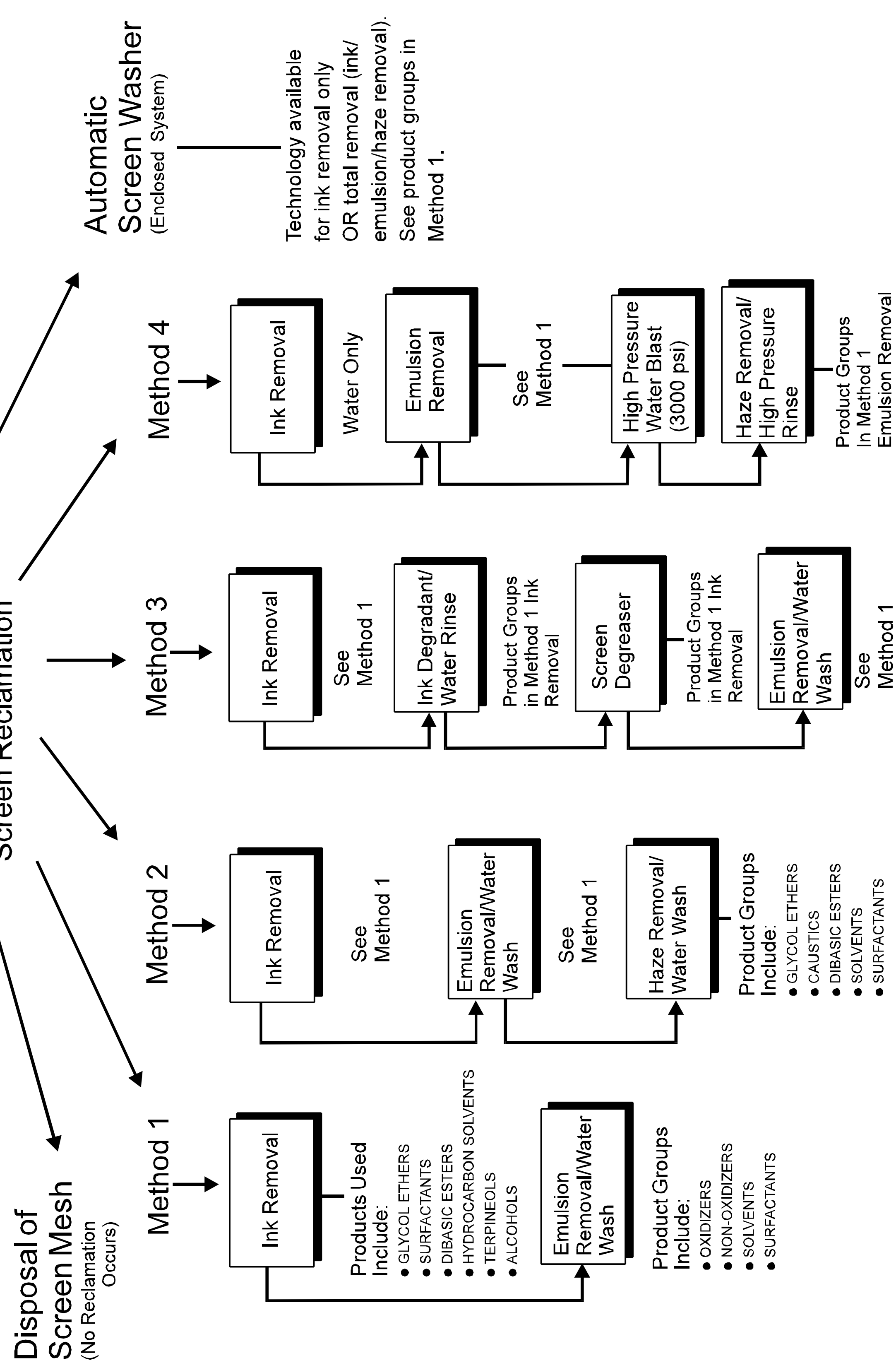
Figure I - 2
Screen Printing Substitutes Tree
Screen Reclamation



Identification of Screen Reclamation Functional Groups

Method 1 in Figure I-2 illustrates that screen reclamation is performed with products from the functional groups of ink removal and emulsion removal only. Under each functional group, some of the categories of chemicals that might be found in these products are listed. Currently, some screen printers only use products from these functional groups when reclaiming screens.

More common among screen printers is the additional use of a haze remover in the screen reclamation process, as depicted in Method 2.

Method 3 was developed by technical staff at SPAI and is currently taught at SPAI in workshop classes; it is referred to by the name "SPAI Workshop Process." It differs from Method 1 and Method 2 in that screen degreasers and ink degradants are used in the screen reclamation process. It also differs from Method 2 in that no haze remover is deemed necessary. Technical staff at SPAI developed this method to avoid the use of caustic haze removers, which can damage the screen mesh.

Method 4 employs both mechanical and chemical technologies to reclaim a screen. No ink remover is applied to the screen during Method 4; instead, removal of ink residue is accomplished by the action of a high-pressure water. A small quantity of diluted emulsion remover is applied to the screen prior to spraying with the high-pressure water blaster. Two different pressures are typically used to remove the emulsion, and subsequently, the remaining ink. If a ghost or haze image is apparent on the screen, a haze remover is sprayed on the screen and brushed from the surface. The pressure spray is repeated and for heavy ghost images, the screen is turned over and the action repeated on the reverse side.

Although the use of an automatic screen washer is not typically found at a screen printing facility, it is a technology that can be used to reclaim screens. Automatic screen washers can be used for ink removal only, or for ink removal, emulsion removal and haze removal. Some automatic processing systems also rinse and dry screens. The screen is immersed in an enclosed system, which then performs the desired screen reclamation function without the labor of the screen reclamation employee.

Potential Screen Reclamation Technologies

Introduction

The methods presented in Exhibit I-2 are traditional screen reclamation processes that use chemicals combined with water washes to clean and reclaim the screen, including a relatively new technology, the automated wash system. In order to fully examine alternatives in search of cleaner technologies, it is useful to identify other process technologies not traditionally used in the printing industry that may accomplish these same ink and the emulsion (stencil) removal functions. Exhibit I-3, Screen Printing Substitutes Tree, identifies technologies used in other industries to remove a material from a substrate that could potentially be modified to reclaim screens, but are not currently used for this purpose. Many of the suggested methods are established technologies in paint stripping and parts cleaning applications. They include blasting methods, stripping methods, and methods that involve pulse light energy. Water-soluble stencils/emulsions, also presented below, represent a product change that will affect other aspects of the printing and reclamation process (e.g., inks used). Except for the sodium bicarbonate blasting method, this CTSA does not evaluate the performance or cost of these technologies in screen reclamation. The intent of Figure I-3 is to bring further thought into how screen reclamation could be performed. The following are reviews of these technologies to evaluate potential feasibility and determine if further research is warranted.

Blasting Technologies

Blasting methods, commonly known as media blasting, use the abrasive and/or fractioning action of a propelled media to remove a coating. Dry media blasting uses air as the propellant for solids of plastic, wheat starch, ice, or carbon dioxide (dry ice); wet media blasting utilizes water as the propellant with sodium bicarbonate as the primary solid. To be effective the media must be hard enough to remove the coating, but soft enough not to damage the underlying substrate. Other factors affecting removal efficiency are application pressure, distance from surface, and angle of application.

There are many aspects that affect the use of blasting technologies for screen reclamation. The equipment required for a media blasting method is media dependent. Each method requires a pressurized air/water source and a specifically designed nozzle for media delivery (plastic and wheat starch units can be interchangeable). In addition, plastic media blasting will require media separation and recycling prior to waste disposal. Wheat starch media blasting may require dust control, but may not require media separation if the spent media and materials removed can be discharged to the sewer. Also, wheat starch is highly moisture sensitive, thus requiring moisture control within the process area. Carbon dioxide media blasting alleviates the potential disposal problems of plastic and wheat starch media blasting; CO_2 pellets, after impacting on the surface, sublime rapidly to the gaseous state, thus leaving only the removed coating behind for disposal. However, storage and pelletizing of CO_2 requires relatively complex, energy intensive equipment. Ice crystal blasting requires the maintenance of refrigeration, ice making, and ice handling equipment.

Media blasting technologies have been successfully applied to large, industrial operations such as building and bridge refinishing, and corrosion removal from process equipment.[21]

[21] Armex Blast Media, (1993).

Figure I - 3

Screen Printing Substitutes Tree

Undemonstrated Technologies In Screen Reclamation

(The cost and performance of these technologies in screen reclamation is undetermined)

Blasting Methods

Dry Abrasives

- PLASTIC BEADS
- WHEAT STARCH
- CARBON DIOXIDE
- ICE CRYSTALS

Wet Abrasives

- SODIUM BICARBONATE

Pulse Light Energy

Laser Stripping

Flashlamp Stripping

Stripping Methods

Dry or Wet Mechanical Sanding

Heat Gun to Burn Off Ink

Liquid Nitrogen (cryogenic) Spray With Dry Blast Media

Use of Water-Soluble Stencils/Emulsion

To allow emulsion removal with water only

c47028-1-2

Starch media blasting units include small hand cabinets, and sodium bicarbonate units can be either fixed or portable, both suggesting they can be used in small-scale applications.[22]

Other characteristics of the media blasting technologies may also lend themselves well to screen reclamation if further research is directed toward development. Small-scale screen reclamation applications may only require changes in operating pressure (reduced pressure), media hardness, and equipment down-sizing. For example, adjustment of application pressure and solids flow rate in the sodium bicarbonate system can control whether just oils and greases are removed from a painted surface, or the paint is removed along with the oils and greases.[23] Wheat starch has been used in industrial applications where surface etch must be avoided on substrates of aluminum and magnesium, and carbon dioxide pellet blasting has been applied to clean precise and delicate circuit boards.[24]

The small media size of wheat starch and sodium bicarbonate may adequately penetrate the weave of the screen, removing both ink and stencil to a degree which could eliminate or reduce the need for a haze removal step. Plastic media, as well as the other media blasting techniques, may cause excessive wear and stretching of the screen mesh. This may result in a shortened screen life and increased screen maintenance (e.g., adjustment of screen tension could be periodically required). It has been documented that crystalline carbon dioxide damages woven fibers, thus limiting its applications in the printing industry.[25] Sodium bicarbonate may have similar damaging effects on the materials of the screen mesh due to the chemical nature of the media which can revert to caustic soda ash in the presence of water and heat.[26] These limitations, however, should not prevent further evaluation of many blasting technologies as a potential clean technology for the screen reclamation process.

Pulse Light Energy Technologies

Pulse light energy technologies use an energy source to vaporize and fracture coatings off of substrates. Laser and flashlamp methods are included in this technology. Laser stripping uses high energy photons generated by a CO_2 or neodymium (Nd) laser to vaporize the coating, leaving an ash behind for disposal. Laser frequency selection can maximize coating removal while minimizing substrate damage; layer-by-layer coating removal can be accomplished with proper control.[27] Initial tests and full-scale operations indicate heat damage of the substrate is a potential problem with laser removal methods.[28] Flashlamp methods use an intense pulse of light to

[22] U.S. EPA Economics and Technology Division, Office of Toxic Substances, *Reducing Risk in Paint Stripping*, (Washington:GPO 12-13 February, 1991).

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] "Light Stripping," *Manufacturing Engineering*, (September, 1992).

[28] Ibid.

vaporize the coating a microlayer at a time. Factors that contribute to the removal efficiency of the flashlamp method include flash repetition rate, intensity, spectral content and flash duration.[29]

The equipment required for the laser and flashlamp methods are unique to the pulse light energy technology. The energy (light) source may have a high capital cost, and energy requirements may be substantial. These units may also be automated. Dust control and waste disposal equipment may be combined in a single vacuum unit, with the volume of waste minimized due to vaporization of the coating. The vapors, however, generated by these methods may require personal protective equipment (respirators), as well as additional process area ventilation and emissions control. Portable, full-scale CO_2 laser units to remove paint from bridges (fitting on a flat bed truck) can cost between $750,000 and $1,000,000.[30]

As with media blasting technologies, pulse light energy technologies have had successful applications in large-scale operations such as bridge and airline fuselage refinishing. These technologies, however, have not been applied to small-scale operations.[31,32] Since many of the operating parameters of laser and flashlamp units can be controlled, it may be possible to optimize these methods to perform small-scale operations such as screen reclamation. The ability of these methods to remove a single or microlayer of material from a substrate may make them useful in a number of industries if they are cost effective. However, substrate heat sensitivity, vapor generation, and high capital and operating costs may limit these processes from entering other markets. A screen mesh, made of polymeric fibers, for example, may be permanently damaged in the reclamation process from the heat generated by the pulse light energy technologies. Also, the fumes generated from the vaporization of inks and stencils, when limited to a closed process area, may cause health and safety hazards. Finally, the current costs of these technologies are prohibitive to all but possibly the very largest screen printers. Pulse light energy technologies, however, may be suitable for screen reclamation and therefore further study may be warranted.

Stripping Technologies

Stripping methods in Exhibit I-3 include sanding, heat gun stripping, and cryogenic methods to remove a coating from a substrate. Sanding methods also use the abrasive properties of a media to remove the coating. The media, either on a sanding block (paper, cloth, etc.) or in a slurry, is applied to the substrate and mechanically worked to remove the coating. Heat guns are intended to either soften or burn the coating which is then scraped from the substrate. Cryogenic methods cool a coating to cause it to contract, weaken and loosen from the substrate. This thermal contraction is accomplished by the application of liquid nitrogen ($-320^{\circ}F$ at atmospheric pressure), and the weakened coating is removed by media blasting methods or another mechanical technique.[33]

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[29] U.S. EPA Economics and Technology Division, Office of Toxic Substances, *Reducing Risk in Paint Stripping*, (Washington:GPO 12-13 February, 1991).

[30] Correspondence between Dean Menke, UT Center for Clean Products, and Simon Engles, HDS Industries, July 1994.

[31] "Laser System Will Automate Paint Stripping," *Laser Focus World*, (June, 1991).

[32] "Nd:YAG Lasers Strip Paint Effectively," *Laser Focus World*, (October, 1992).

[33] U.S. EPA Economics and Technology Division, Office of Toxic Substances, *Reducing Risk in Paint Stripping*, (Washington:GPO 12-13 February, 1991).

Stripping methods utilize diverse, technology-specific equipment. Sanding methods have the potential to be automated, but are traditionally manual operations consisting solely of a sanding block or slurry applied to the surface to be refinished. Heat guns typically utilize an electrical power source to heat a metallic element held in contact with the coating. The heat softens or burns the coating thus simplifying removal. After heating, the coating is promptly removed by a scraping device or spatula. Cryogenics is the most energy intensive method of the stripping technologies. Equipment includes units to liquify nitrogen, a chamber for substrate-liquid nitrogen contact, and media blasting equipment.

Most stripping methods mentioned here appear to have a high potential to damage the screen. Manual sanding methods could damage the screen in areas where there is no stencil/emulsion and sanding media is in direct contact with the mesh. As with pulse light energy technologies, the polymeric materials used for screen mesh may be permanently damaged if subjected to temperature extremes; therefore, the heat gun method may not be feasible. Cryogenics, with its extreme operating temperatures (cold) may also damage screen mesh. However, the thermal resistance of most polymers to cold is greater than to heat, and the process may warrant further research. However, current cryogenic technologies are probably too costly for the average screen printer.

Stencils/Emulsions Chemistry

The substitute technologies presented above focussed on methods that could be used to remove a stencil/emulsion that would traditionally be removed with chemical products. The use of water-soluble stencils/emulsions, however, could eliminate the need for chemical removal products as well as any of the above mentioned alternatives. Certain products of the indirect stencil/emulsion process are water soluble and can be removed using only water to reclaim the screen; other indirect stencil/emulsion products may use an enzyme or gelatin film decoater.

The image printed on a substrate in the screen printing process is defined by the stencil -- the area of the screen on which there is no emulsion blocking the flow of ink through the mesh to the substrate. The stencil/emulsion is applied to the screen mesh using direct or indirect processes. In direct processes (either capillary direct or direct emulsion), the printed image is photographically developed after the emulsion is on the screen. This is accomplished by the following procedure:

1. apply a water dispersion of polymer and sensitizers over the screen,

2. allow this to dry (this dried dispersion is still completely water soluble until exposed to curing light),

3. block the desired image from the developing light,

4. expose the screen to light (usually UV), thus curing the dried dispersion (a reaction between the sensitizers and polymer creating a cross-linked emulsion film), and

5. wash the uncured dried dispersion away with water.

During screen reclamation, emulsion remover is required for these products to break the cross links and destroy the polymer network.

Indirect processes, on the other hand, photographically develop the image of the emulsion away from the screen and then apply the developed stencil/emulsion to the mesh. The procedure to accomplish this is as follows:

1. expose the thin film emulsion to the desired image,
2. develop the image using a developing solution in a shallow tray,
3. wash away the uncured emulsion (image) with a aerator water nozzle,
4. adhere thin film emulsion to screen mesh and allow to dry, and
5. remove the supporting plastic film from the dried emulsion.

This stencil/emulsion can be removed during screen reclamation using an enzyme or gelatin film decoater to soften the emulsion, which is then removed with a water spray. However, discussions with printers and vendors of indirect emulsions indicated that a warm water wash alone can be used to adequately remove the stencil/emulsion following ink removal. The water wash will take approximately five minutes to sufficiently soften the emulsion (longer than a process using chemicals), but this process time is chosen over chemical costs and disposal.[34] Limitations of this water-soluble stencil/emulsion lie in the inks used (no water-based inks, only oil- and rubber-based can be used) and possibly the operating conditions (low humidity required).

Conclusions

Many of the substitute technologies presented in Exhibit I-3 possess properties and characteristics that may be applicable to the screen reclamation process performed by screen printers. The technologies presented here are not exhaustive, and were solely intended to bring further thought into the area of potential alternative technologies. Currently, these technologies have high-tech applications, and therefore may not be economically feasible for the average printing establishment. However, that is not to say that further research into these technologies, and their continued development, could not result in more cost-effective, easy-to-use applications.

Issues that should be addressed when considering these alternative technologies in future research include the following: effectiveness of ink, emulsion and haze removal; cost, both capital and operating; potential of damaging screen; risk to human health and the environment from use of the methods; waste generation and disposal; and energy and natural resource use. A multi-media approach must be taken when researching the potential applications for these technologies. For example, wheat starch and bicarbonate media blasting may be cleaned by washing with water and disposing of the waste down the drain. This may simplify the cleaning process, but consideration must be given to the local disposal and permitting requirements of wastewater pretreatment and disposal; the inks and emulsion materials also washed down the drain could impart an additional load on the wastewater treatment facility, and have the potential to be hazardous. Also, as mentioned above, vapors generated from coating destruction by pulse light energy technologies may require personnel protection equipment, ventilation and control.

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Alternative Sodium Bicarbonate Screen Reclamation Technology

General Summary of the Technology

The sodium bicarbonate screen reclamation technology consists of an enclosed spray cabinet where pressurized sodium bicarbonate (baking soda) and water are sprayed onto the parts inside the cabinet to clean them. Currently, this technology is used primarily for removing coatings, such as paint, grease, or teflon from metal parts. As part of the DfE Performance Demonstration, the sodium bicarbonate technology was tested to determine if it is potentially adaptable as an alternative screen reclamation technology. A risk assessment was not conducted for the use of this technology in screen reclamation. However, it is known that sodium bicarbonate (baking soda) is a fairly innocuous chemical that is not a skin irritant and has a low toxicity; it is a common ingredient in baked goods, toothpaste, detergents, air fresheners and deodorants.

Prior to this study, the sodium bicarbonate technology had never been tested for screen reclamation applications. The cleaning procedure used during the test was a method developed for cleaning metal parts, and adapted to screen reclamation. The screen was placed inside the enclosure and held under the pressurized baking soda spray to remove the ink, emulsion and haze from the screen simultaneously. The advantage of such a system for screen reclamation is that no hazardous chemicals are used, and the need for ink remover, emulsion remover, and haze remover is eliminated. In preliminary testing, the sodium bicarbonate technology showed potential for effectively removing solvent- or water-based inks. Results on a screen with UV ink, however, were poor. In all cases, further development and testing are needed before the technology could be used in a screen printing facility.

Application Method

At this time, the sodium bicarbonate-based technology has not been developed specifically for screen reclamation. It has been successful in replacing hazardous cleaning chemicals in other applications such as in metal parts degreasing and paint and adhesives removal. To determine if this technology could be adapted for screen reclamation, three screens were prepared for cleaning: one with solvent-based ink, one with UV-curable ink, and a third screen with water-based ink. All tests were conducted at the equipment manufacturer's facility. This particular manufacturer developed the enclosed spray cabinet, and is a distributor of sodium bicarbonate. Because this technology is still under development and is unproven for screen reclamation, no demonstrations were conducted at printing facilities. An observer from the DfE Printing Project was present to record information on the system's performance in cleaning the three test screens.

Tests were conducted in two different enclosures. Half of each screen was first cleaned in an enclosure which delivered dry, pressurized baking soda to the screen. The second half of each screen was cleaned in an enclosure which delivered both pressurized water and baking soda. The same cleaning procedure was used for the two systems. After excess ink was carded off, the screen was placed inside the enclosure with the flat side down. The door was locked and the operator placed his hands through the gloves built into the box. By stepping on a foot pedal, the operator started the flow of pressurized sodium bicarbonate from the fan nozzle mounted in the top of the enclosure. The fan nozzle, designed by the enclosure manufacturer, spreads out the impact of the sodium bicarbonate to reduce the stress on the screen. The nozzle used for testing dispersed the sodium bicarbonate over an area approximately one inch wide by three inches long. On the wet system, the same nozzle was used to deliver the sodium bicarbonate, and the water nozzle was mounted on the fan nozzle, so that the water and baking soda mixed together as they were discharged. Holding the screen under the fan nozzle, the operator moved the screen from side to side. The operator was able to see where the ink or emulsion remained on the screen by watching through the primary viewing area. This window was purged with air to enhance visibility by clearing the dust from the viewing area. When the first side was clean, the operator flipped the screen over and repeated the cleaning procedure on the other side until all ink, emulsion, and haze were removed.

During the test, the following parameters were used:

- **Sodium Bicarbonate:** 75 micron particle size
  Delivered at 1 to 1.5 pounds/minute
  Sodium bicarbonate delivered at 5 to 30 psi
  Water delivered at 200 to 250 psi

- **Screen:** Polyester mesh mounted on wood frames
  Dual-cure emulsion
  13" x 23" outside diameter

- **Inks:** Solvent-based ink = Naz-Dar 9700 Series All Purpose Ink 9724 Black
  UV-cured ink = Nor-Cote CD 1019 Opaque Black
  Water-based ink = TW Graphics WB-5018 Black

- **Ink application:** Each type of ink was applied to one screen, carded off, and the screen was allowed to dry for 18 hours before starting the cleaning test.

Alternative System Performance Results

Dry Cleaning Process

During the demonstration, several different application methods were tested to optimize the system performance. First, the screen with solvent-based ink was cleaned in a dry box; only pressurized baking soda was delivered, without any water. At a pressure of 5 psi, some of the ink and emulsion were removed, but very slowly. A heavy haze and some ink and emulsion residue remained. To accelerate the removal, the pressure was increased to 10 psi. This pressure proved to be too high and the screen developed pin holes and eventually ripped. The pressure was reduced to 5 psi. To reduce the stress on the mesh, a flat plate was placed behind the screen. Screen damage was reduced, but was not eliminated.

Similar results were obtained with the water-based ink screen. Significant ink and emulsion residue remained on the screen after cleaning a 4 inch by 4 inch area for 5 minutes. Again, screen wear and small holes were visible in some areas. After these disappointing results, dry testing was discontinued in favor of the wet delivery system. The water serves to soften the sodium bicarbonate, making it less abrasive than the dry delivery process. Because of the softening effect, a higher pressure could be used with the wet delivery system without damaging the screen.

After such poor performance was demonstrated using the dry cleaning process on the solvent- and water-based ink screens, the decision was made to skip the dry process for the UV ink screen, and start with the wet cleaning process. Additionally, the UV ink does not dry (unlike the solvent- and water-based inks), and the manufacturer felt that the application of the dry sodium bicarbonate would stick to the wet ink across the entire screen, instead of removing the ink. If the sodium bicarbonate was covering the screen, the wet cleaning process test would not be valid.

Wet Cleaning Process

All three screens were tested using the wet process. Water was sprayed onto the screen at 200 to 250 psi, while the sodium bicarbonate was sprayed out of a fan nozzle at varying pressures. On the screens where the dry process was used to clean half the screen, the wet process was used for the other half. Performance clearly improved using the wet technology.

On the screen with UV ink, the sodium bicarbonate-based technology was completely ineffective. After about 5 minutes of cleaning, there was almost no removal of the ink or the emulsion. The operator increased the pressure to 20 psi to improve the system performance. When there was no improvement at 20 psi, the pressure was increased to 30 psi. Even at the higher pressure, there was no significant removal of the ink or the emulsion from the screen. The operator put a glass plate behind the screen to concentrate the sodium bicarbonate and to support the screen, but this did not help to remove the ink or emulsion. After approximately 10 minutes of cleaning without any noticeable removal of ink, the test was stopped.

The solvent-based ink screen was cleaned first. At 5 psi, it took approximately 5 minutes to remove the ink and emulsion from a 4 inch by 4 inch area of the screen. At this point the screen was visually inspected. There was no visible damage to the screen, so the pressure was increased to 10 psi. Another 4 inch by 4 inch area was cleaned, and at 10 psi, it took approximately 3 minutes. Some areas of the emulsion came off in stringy pieces. After cleaning the rest of the screen, a light haze remained in the image area. Around the edges of the screen where the ink was fairly thick, a heavy residue remained, but there was no ink or emulsion residue in the image area. Total screen cleaning time for the half of the screen that was cleaned with the wet cleaning process (a 10 inch by 10 inch area), took approximately 16 minutes.

Performance on the screen with water-based ink was similar to the screen with solvent-based ink. On the water-based ink screen, all testing was conducted with the sodium bicarbonate pressure at 10 psi. Initially, the ink started to come off fairly well, but very slowly. After a few minutes, the ink began flaking off, instead of dissolving. The flaking made it significantly easier to remove the ink. Again, the emulsion came off in stringy rolls. Ink residue remained around the edges of the screen, but the image area was clean with a very slight haze. After closer inspection, some very small spots of ink residue were apparent. In an effort to remove these spots, the operator concentrated the spray on the small effected area. After one or two minutes, this concentrated pressure ripped the screen. Total cleaning time for the portion of the screen that was cleaned with wet cleaning (10 inches by 10 inches), was approximately 13 minutes.

Technology Potential

The cleaning procedures used during testing were the methods used for cleaning metal parts and were not specifically developed for screen reclamation. With further testing and research, this application method could be improved to clean the screens faster and with less possibility for screen damage. For example, during the test, a piece of rigid material (safety glass) was held behind the screen to reduce the pressure on the mesh. From the limited testing performed, this support seemed to concentrate the cleaning media on the desired area while reducing the stress on the screen. As another change that may improve performance, the operator suggested using hot water. When cleaning the screens with solvent- and water-based ink, the emulsion came off in stringy pieces that rolled off the screen. This reaction did not seem to increase or decrease the removal efficiency, however, hot water may help dissolve the emulsion, potentially accelerating the removal process. A third possible improvement in the application technique may be to add a small platform inside the enclosure which would help the operator hold the screen closer to the spray nozzle.

In addition to equipment modifications, several other variable changes that may be specific to each facility should also be investigated. These factors include increasing or decreasing the particle size of sodium bicarbonate, changing the pressure of the water or the sodium bicarbonate, and changing the rate of delivery of the medium. With further research into improvements in the sodium bicarbonate application, this technology could potentially reduce chemical use during screen reclamation for printers using solvent-based or water-based inks.

Cost

Because the equipment used during testing was not developed specifically for screen reclamation, it is difficult to estimate what the actual cost would be for a screen printing facility to implement this technology. However, some rough estimates of equipment and chemical use are available. The equipment used in the wet cleaning could range in cost from $32,000 to $52,000. This estimate is subject to a wide range of actual operating conditions, including the type of filtration and waste treatment that is necessary; the filtration and waste treatment needs will vary depending on the ink and emulsion components on the screen. The blast media can cost between $0.65 to $0.75 per pound, with the less expensive price available for large volume purchases. Further research into the use of the sodium bicarbonate-based technology in screen reclamation would give a better indication of the costs that could be expected for a typical screen printing facility.